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time to apply the fungus is when the maximum number of crawlers are out, i. e. about a week after the culmination of the June flight of adults. The yellow aschersonia, however, should accordingly, be applied about the middle of July. The same principle applies to the scale-infesting fungi. They should be sprayed on the trees when the maximum number of scale crawlers are out.

Mr. A. C. Brown spoke on sweet-potato certification.

The committee on truck crops reported the control of aphids to be one of their most serious problems.

RELATION OF ENVIRONMENTAL FACTORS TO WING DEVELOPMENT IN APHIDS¹

By ARTHUR C. MASON

The generally accepted theory of most entomologists and experimenters on the subject is that winged forms of aphids are produced only when the continued existence of the apterous forms, under conditions then existing, might prove disastrous to the species. This occurs always in the fall in cold climates when sexual forms are produced, the males of which are usually winged, and also at any migrating season in the case of those species which live on two or more different host plants. There are also many other causes attributed to these adaptive variations. Among the factors which may be potent in acting as effective stimuli for wing formation are crowding on the host and hence lessening of the food supply, unusually high or low humidity, early lowering of temperature in autumn, changing constitution of the sap of the plants by chemical means, etc.

In collecting aphids it was noted that usually both winged and apterous forms occurred in the same colony; also, in the life history work with *Myzus persicae*, that some of them would be winged and others apterous. In several cases plant lice which were apterous when collected would develop wings when kept in the laboratory for a day or two. The question often arose as to why some of these forms were winged and some apterous when living under the same conditions, and as to whether the environment of the aphids in the breeding jars had an effect on this. Hence a series of experiments was planned to prove or disprove some of these theories.

¹A synopsis of Part III of thesis entitled "Systematic and Biological Studies of Some Florida Aphididae", presented by the writer in 1915 to the University of Florida for the degree of Master of Science. This is the third and concluding paper of the series.

Species Used. For carrying on these experiments the following three species of aphids were mostly used: *Lachnus pini* L., *Myzus persicae* Sulz., and *Aphis gossypii* Glov. These aphids could be found in greater or less abundance at all times of the year and both winged and apterous forms occurred naturally in the colonies. They continued to reproduce viviparously all through the winter and hence a supply of adults could always be obtained. The last two species lived on a number of different host plants and so could be raised under varying conditions. Another species, *Macrosiphum davisii*, had been observed for a year on the rose bushes and no winged forms ever occurred. Hence some work was done to try to produce some individuals with wings.

EFFECT OF INJURY TO HOST PLANTS

Starting out with what appeared to be the most promising methods of securing results, some experiments were run to determine the effect of injury of the host plant on the aphids. For this work some small pine trees infested with *Lachnus pini* were selected. The object was to injure the branches by girdling or partial girdling so as to shut off the flow of sap in the branch and determine the effect on the aphids.

Branch A was injured by cutting the bark and cambium layer for one-third of the distance around it; branch B had the bark cut through the cambium layer for two-thirds of the distance around; branch C was a check, uninjured. On each of these branches was placed a small colony of *Lachnus pini* in a cage. Another small tree was completely girdled around the base and a colony placed on it in a manner similar to the others. This colony is designated as D. A third tree was uninjured and a colony placed on it for a check, designated as E. These experiments were begun in November and were run for about two months, the results being recorded two or three times a week. The number of winged forms found each time were counted and the results tabulated.² The table shows that winged forms were produced in all the cages. On the first tree check colony C had approximately as many winged forms as colonies A and B which were on injured branches. Colony D also had a large number of winged forms but check colony E for a few weeks produced only apterous forms. Later on, however, winged ones appeared.

²The tables are necessarily omitted because of lack of space and instead the results are summarized. The photographs illustrating the work are also excluded.

A little later the experiment was repeated. Colony F was placed on another uninjured tree and colony G on a small tree which was girdled in a manner similar to the tree in the previous experiment. Colonies H and I were checks on uninjured branches of another tree. These were carried on as the previous experiments for several weeks with no decided results on wing production by injuring the host plant. The checks produced winged aphids about as consistently as did the injured limbs. Check colony E appeared for a time to be an exception to this rule, and it was thought that the tree on which they were living might be the cause of this. Consequently some of the apterous aphids from colony E were taken out and three new colonies started from them. Colony J was placed on a branch near A and B on tree No. 1, which had produced winged forms; colony K was placed on a limb of the girdled tree No. 4 by the side of colony D which had also produced winged forms; and colony L was moved to a new limb of tree No. 5, near colony E, for a check and to counteract any effect of moving the aphids to other trees. As the results show, winged aphids were produced not only in each of these three colonies, but also a little later in the original colony E.

About two months after being girdled one of the trees was turning very yellow from the effects. Therefore, two colonies of aphids were placed in cages on limbs of this tree, and two other colonies were placed on limbs of a healthy tree, as a check. All four colonies were taken from the same colony containing both winged and apterous forms. Here, also, during two months' time, winged forms were found in the checks in about the same ratio as in the colonies on the girdled tree. Therefore, the unhealthy condition of a pine tree due to girdling or any change which it may cause in the sap of the tree will not cause the aphids on it to produce wings in increased numbers over those on healthy trees.

Effect of Crowding on Wing Production. In many colonies it was observed that no winged forms appeared until several days after the colony was started, or until it had increased in size and often covered the limb thickly. Consequently the question arose as to whether or not the large number of aphids there caused the production of wings, either directly, or indirectly, by lessening the food supply. To investigate this point two colonies were started on a girdled tree. The first one, colony M, was placed on a limb of this tree on December 11 and allowed to

grow. A week later another small colony, (N), taken from the same place as the others, was placed on another limb. Colony M had a start on colony N and should be more numerous and show any effects of crowding sooner than N. The results show no difference. In fact colony M produced winged forms before N was even started and while there were only a few aphids there, and continued to produce them as long as the colony lived there. Therefore crowding as a probable cause of wing production was given up.

*Effect on *Myzus persicae* of Injuring Cabbage Plants.* This experiment was tried in the greenhouse insectary and its object was to see if unfavorable conditions of growth for a cabbage plant will cause aphids of the species *Myzus persicae* growing on it to produce wings and seek a new plant. Twelve potted cabbage plants were placed on the bench and covered with lantern globes, and divided into three groups. The first four had a cord tied lightly around the stem which would shut off the flow of sap to some extent. The next four were given no water and allowed to dry up. The third four were kept in a normal condition and used as checks. Each of the plants had a number of aphids placed on it and left for two weeks, the results being recorded each day or two. As the table shows, winged forms were produced on all of the plants without discrimination. In fact the total number on the four plants of each group is about the same. The results, therefore, do not argue in favor of the unhealthy condition of plants causing wings.

Mature Aphids. Eight adult apterous *Lachnus pini*, which had already produced some young, were placed on a cut stem which had already become partially dried out. All died in less than a week and produced no wings. It is hardly reasonable to believe that an adult could develop wings.

EFFECT ON APHIDS OF ADDING CHEMICAL SOLUTIONS TO THE FOOD OF THE HOST

Some experiments were next run to determine if changing the sap of the host plant by adding chemical solutions to its food would cause aphids on it to produce wings in order to seek a new host. Some of these chemicals would undoubtedly be taken up by the plant and consequently added to the dietary of the aphids. First, some cabbage plants which were infested with *Myzus persicae* were watered with solutions of magnesium sulphate of varying strengths. Small pots were filled with clean

white sand and some small cabbage plants, whose roots had been washed clean of all earth, were placed in them. The object was to remove all plant food, as far as possible, and give the plants nothing but what was in the solutions added. The plants were placed under lantern globes in the laboratory and divided into four groups of two plants each. One lot was watered with a 1% solution, one with a 5% solution and one with a 10% solution of magnesium sulphate, and the other with distilled water for a check. The sand was kept moist by watering every day and the results recorded daily. The 5% and 10% solutions were found to be too strong and the plants soon died. Some winged forms were found on all but two of the plants however.

The experiment was then repeated, this time using three per cent solutions which would not affect the plants so quickly. Eight cabbage plants were cleaned and potted as before and divided into four groups. One group was watered with a 3% solution of each of the following: magnesium sulphate, sodium chloride, tannic acid, and one group with distilled water for a check. In no case did the plants live more than a few days. They soon began to turn yellow, probably from lack of food, and consequently the aphids left them and started wandering around and died. As the table shows, wings were produced in some of them, but without much consistency. Although the checks produced no winged forms, one plant in each of the other groups showed none also. The experiment did not run over a long enough period to be conclusive. There was not sufficient time for the aphids to mature and show the effects of the chemicals. Besides we cannot prove that the plants took up any of the chemical solutions added, since the roots have the power of discriminating between the available foods. Therefore some attempts were made to rear them on cut stems in chemical solutions.

Experiments with Cut Stems. Eight young orange tips were cut from a tree and placed in small pots of clean white sand which were covered with lantern globes and set in the greenhouse on a shaded bench. On each of these cuttings were placed a number of aphids of the species *Aphis gossypii*. Two of them were watered with a 3% solution of each of the following chemicals: magnesium sulphate, sodium chloride and citric acid; and two were watered with distilled water for checks. The results were recorded as long as the cuttings kept fresh and the aphids

lived on them. However after a few days the leaves wilted and dropped and the aphids began to die. Some winged ones were produced on all but one of the cuttings, but with no regularity.

A little later the experiment was repeated, this time with *Myzus persicae* on orange cuttings. The cuttings were prepared as described above. Three or four dozen aphids were placed on each and watered with the same solutions as above and in the same order. The results as recorded show that wings were found in all but one, a cutting watered with sodium chloride solution. This cutting did not last very long before the leaves turned brown and dropped. In fact the cuttings watered with the chemical solutions showed the effects sooner than the checks in all cases. In this experiment the checks produced more winged specimens than any of the others except those watered with magnesium sulphate which produced about an equal number. Possibly this can be explained by the fact that the cutting did not wilt so quickly and hence more of the aphids had an opportunity to mature. At any rate, the wilting of the stems or the effect of the chemicals cannot be said to produce wings.

Lachnus pini on Pine Cuttings. Four branches were cut from a pine tree and placed in bottles one each containing a 3% solution of magnesium sulphate, sodium chloride and citric acid and distilled water. On each of these branches were placed about four dozen immature aphids of *Lachnus pini* which were allowed to mature. The mouths of the bottles were plugged with cotton and the whole bottle and stem covered over with a bell jar. Results show that in all cases except the check a majority of the aphids died while still immature and in the check also a large number died before becoming adult. The greatest mortality was noted on the stems kept in sodium chloride and citric acid. The leaves soon began to dry up there and the aphids died. In all cases however some winged ones were produced but most in the check. Here also we can say this is due to the fact that more of the aphids lived to become adult on the check.

Injections of Chemicals into Plants. To make more sure of getting the chemicals into the sap of the plant and thus adding them to the food of the aphids, they were injected into the growing stems with a hypodermic needle. This method was used on both cabbage plants and orange trees. Eight growing healthy cabbage plants were potted and placed under lantern globes in the open-air insectary. The same chemicals as used above were

injected into the stems. In two each was injected magnesium sulphate, sodium chloride and citric acid, in one distilled water and in one nothing. On each of these plants were placed twelve immature specimens of *Myzus persicae* about one week old. The plants were watered and kept in a healthy condition, and the aphids were allowed to mature there. The results show a few winged ones for each of the solutions, but not conclusive in favor of the chemicals. On one plant of each group all matured apterous.

The same experiment was later tried by injecting some of each of these chemicals into young orange tips and tying up in each twelve immature *Myzus persicae*. Chemicals in same order as above. Here, also some winged ones were produced in each case, but most in the checks.

Trials with Rose Aphids. A species of green rose aphid, probably *Macrosiphum davisi*, had been watched for over a year on rose bushes and no winged specimens were ever seen. Therefore an attempt was made to produce wings on some of them. Three cuttings of rose were made and placed in sand and watered: No. 1 with 1% magnesium sulphate, No. 2 with 5% magnesium sulphate, and No. 3 with water. On each cutting was placed several of the rose aphids. The rose cuttings however only remained fresh for a few days, when they wilted and the leaves fell. The aphids died and no wings were produced. The experiment was repeated a little later, this time by changing the cuttings about every three days and transferring the aphids to the fresh cuttings. In this way three generations were raised and about thirty individuals in each. All were apterous. No winged forms were produced not even in the second and third generations.

Effect of Chemicals on Plants. In all cases where cut stems were placed in chemical solutions it was observed that the checks in distilled water would last longer. A number of tests with cuttings used in solutions of varying strength of the above chemicals showed this always to be the case. The chemical solutions caused wilting the second day and dropping of the leaves in two or three days. The checks stayed fresh for five days. In all these cases the results were conclusive enough to show that the chemical solutions do have a deleterious effect on the cut plants, and plant physiologists agree on this point. Where the solution is strong enough it will have an osmotic pressure, which will

draw the sap from the cutting and consequently cause it to turn brown and wither. The fact that the checks always lasted longer, and therefore the aphids lived longer, is sufficient cause for the greater number of winged forms there. The experiment failed, however, to show that the chemicals in the stems will cause the aphids to produce wings, since the checks always produced as large a number of winged forms.

(To be continued)

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